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A NEW SPECIES OF FARRODES (EPHEMEROPTERA: LEPTOPHLEBIIDAE: ATALOPHLEBIINAE) FROM SOUTHERN TEXAS

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Abstract.—***Farrodes texanus*** n. sp. from southern Texas is described from nymphs and male and female imagos. This report includes the first specific records of the genus from outside the West Indies. The new species resembles the three previously described species of *Farrodes* in a number of morphological respects. However, the degree of difference in male genitalia structure and the distinctive abdominal color pattern indicate that *F. texanus* is not closely related to West Indian species, but rather represents a separate evolutionary line. The new species is probably derived from a South American ancestor that invaded Texas during the early Pleistocene. *Farrodes texanus* is relatively uncommon, known thus far only from a few scattered localities in southern Texas, where it apparently is restricted to small, rocky-bottomed, clean-water streams.

Collections of benthic macroinvertebrates during water quality investigations conducted since 1981 have resulted in the discovery of a new leptophlebiid mayfly from southern Texas, described herein as *Farrodes texanus* n. sp. These constitute the first specific records from outside the Caribbean area, the genus formerly having been reported from the West Indian islands of Cuba, Jamaica, and Grenada (W. L. Peters, 1971).

Methods and Materials

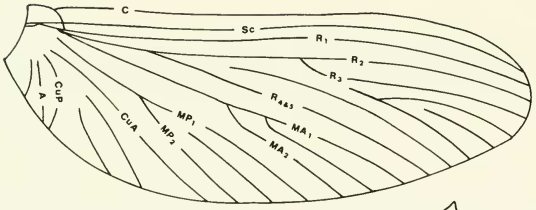
Nymphs were collected using a Surber square foot sampler or a d-frame aquatic net, or by handpicking from overturned rocks. All imagos were obtained through rearing of mature nymphs. Rearing was accomplished in a polystyrene container with water agitated by air stones, and in an air powered, artificial stream modified after Lawson (1982). In each instance, stones from the reference stream were placed in the rearing chamber to provide food material for nymphs. Both rearing techniques produced excellent results.

Physicochemical data used to characterize the nymphal habitat are available for all seven collection localities, as all collecting has been in conjunction with intensive water quality surveys conducted by the Texas Water Commission. Each survey was diurnal in nature, with dissolved oxygen, temperature, pH, and specific conductance measured 3 or 4 times from predawn to sunset. These data, therefore, represent physiochemical extremes for a particular date and locality. Data for other physicochemical parameters are based on composite samples, with equal aliquots composited on each sampling run. Intensive survey methodologies are described in detail in Buzan (1982).

Farrodes texanus Davis, New Species

Figs. 1–10

Homothraulus sp.: Edmunds, Jensen, and Berner, 1976: 224; Edmunds, 1978: 79.



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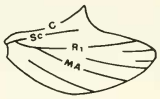

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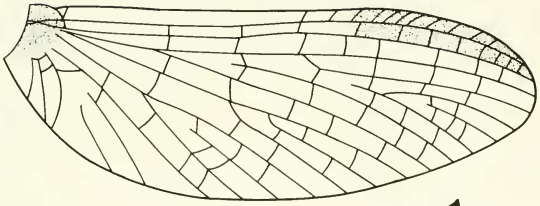

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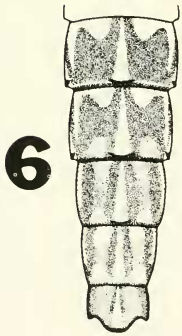

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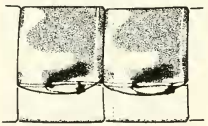

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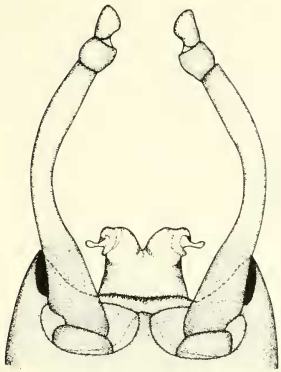
Figs. 1–7. *Farrodes texanus* n. sp. 1, Schematic adult fore wing, showing abbreviations of venational terminology used in this paper. 2, Same, hind wing. 3, Adult fore wing. 4, Adult hind wing. 5, Hing wing enlarged. 6, Dorsal view, abdominal segments 6–10, male imago. 7, Lateral view, abdominal segments 6 and 7, male imago.



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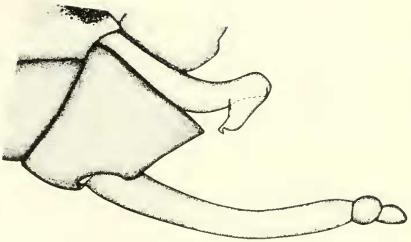

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Figs. 8, 9. *Farrodes texanus* n. sp. Genitalia of male imago. 8, Ventral view; 9, Lateral view.

Farrodes sp.: Edmunds, 1982a: 243, 1982b: 372, 1984: 97, 125.

Male imago (in alcohol).—Length: body, 4.6–5.0 mm; fore wings, 4.6–5.1 mm; terminal filament, 8.4–9.7 mm; caudal cerci, 5.1–5.9 mm. Upper portion of eyes buff, lower portion dark gray. Head light yellowish-brown; carinae and mouthparts washed with black. Antennae light brown, flagellum pale yellow. Base of ocelli black, remainder white. Thorax yellowish-brown, carinae darker, sutures lighter; prothorax washed with brown, pronotum with dark brown markings and black margins; pleural areas dorsal to base of legs and near anterior base of fore and hind wings washed with brown. Legs pale yellow; coxae suffused with black; apical half of prothoracic femora variably washed with light brown, apex of mesothoracic femora light brown, and apex of metathoracic femora brown. Ratios of segments in fore legs, 0.54:1.00 (1.78 mm):0.07:0.33: 0.25:0.14:0.09. Tarsal claws of a pair dissimilar, one apically hooked, the other obtuse, padlike. Wings (Figs. 1–5): longitudinal veins of fore and hind wings buff, cross veins paler; membrane of fore and hind wings hyaline, except distal third of cells C and Sc of fore wings translucent, and base of wings buff. Fork of vein MP of fore wings symmetrical; base of vein ICu_1 of fore wings not attached to vein CuA or CuP. Abdomen (Figs. 6, 7): segments 1–6 semihyaline, segments 7–9 opaque. Each tergum washed with dark reddish-brown, with pale yellow lateral margins, and with five principal areas of pale yellow lightening: (1) a median, anteriorly-directed, triangular mark gradually increasing in width from tergum 1 through tergum 6 or 7, then narrowing posteriorly, (2) two anterior, submedian, oval marks, and (3) two anterior, sublateral, rectangular marks. Sterna 1–7 pale yellow; sterna 8 and 9 slightly darker, washed with light brown. Spiracles black, tracheae semihyaline washed variably with black. Genitalia (Figs. 8, 9): apical one-third of penes divided, a ventral appendage arising from apex of each penis lobe; posterolateral margins of styliger plate produced, extending posteriorly dorsal to forceps; basal one-third of forceps segment 1 light brown, remainder of forceps and penes pale yellow. Caudal filaments semihyaline, white to pale yellow.

Female imago (in alcohol).—Length: body, 4.4–4.9 mm; fore wings, 4.7–5.3 mm;

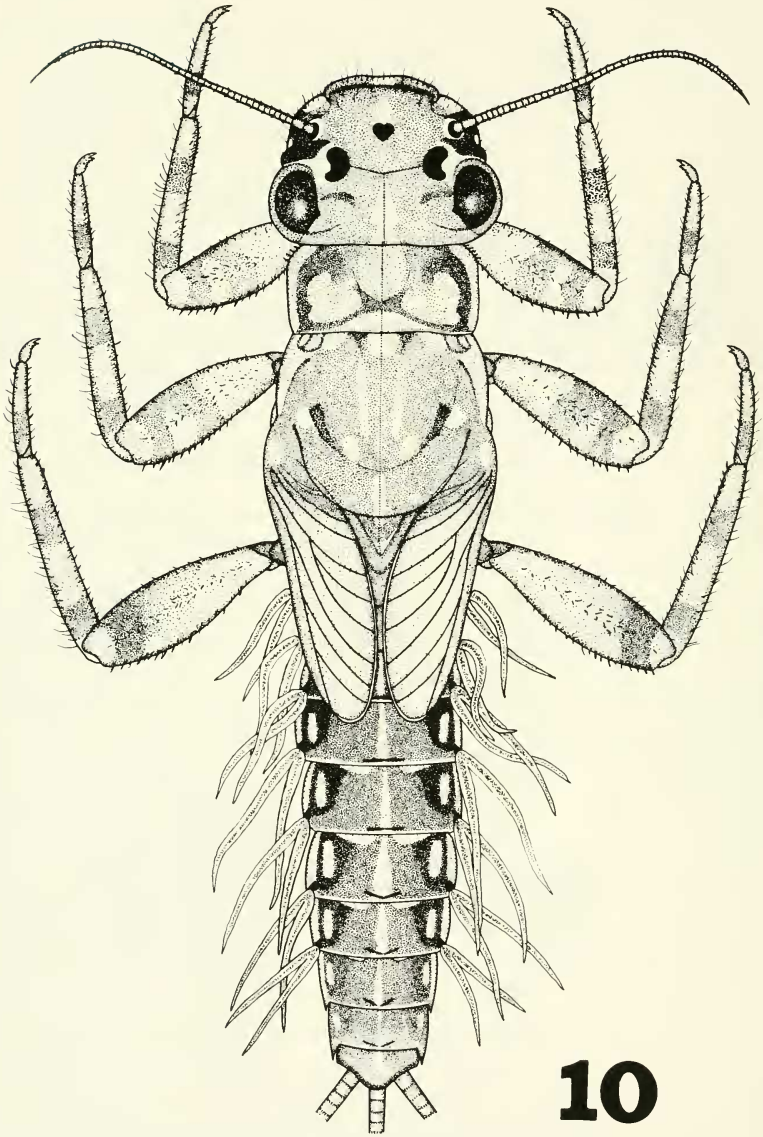

Fig. 10. *Farrodes texanus* n. sp., dorsal view, female nymph.

terminal filament, 7.3–8.7 mm; caudal cerci, 4.7–6.0 mm. Eyes dark gray. Head buff, carinae and mouthparts washed with black. Antennae light brown. Color of thorax, legs, and wings, and aspects of wing venation, essentially as in male imago. Abdomen: terga 1–9 washed with dark reddish-brown, generally darker than in male imago, especially in anterior segments. Lightening pattern of terga relatively similar to that in male imago (Figs. 6, 7), except median triangular marks not increasing gradually in width posteriorly from tergum 1, but rather uniformly very narrow or absent on terga 1–4, suddenly becoming distinctive on tergum 5, and attaining maximum width on 6 or 7 before narrowing posteriorly. Spiracles and tracheae as in male imago (Fig. 7). Sterna pale yellow, lateral margins of sterna 1–4 or 5 often washed with light brown. Apex of ninth sternum produced, entire, and bluntly rounded. Caudal filaments semihyaline, light brown.

Mature nymph (in alcohol) (Fig. 10).—Length: body, 4.3–5.6 mm; terminal filament, 9.5 mm; caudal cerci, 5.2–5.3 mm. Head prognathous; dorsum brown with pale yellow markings as in Fig. 10; venter pale yellow. Antennae 2½ times maximum length of head, brownish-yellow in color. Thorax light brown with brown and pale yellow markings as in Fig. 10. Legs pale yellow; femora with a brown, transverse, apical band; tibiae with brown, transverse, basal and subapical bands; tarsi with a brown, transverse, basal band. Tarsal claws with 14–18 denticles becoming progressively larger apically, except apical denticle much larger. Abdominal terga washed with brown, with pale yellow markings essentially as described for imagos; sterna pale yellow. Posterolateral spines present on abdominal segments 8 and 9, that on 9 larger. Abdominal gills present on segments 1–7, all alike, each portion of gills long, slender, and gradually tapering to apex. Length-to-width ratio of middle abdominal gills 10:1 to 12:1; gill membrane translucent, gray, tracheae black. Caudal filaments brownish-yellow, with darker annulations at articulations throughout length of filament.

Etymology.—The species is named for the state of Texas, to which it apparently is endemic.

Type material.—Holotype, ♂ imago, Texas: Caldwell County, Plum Creek at FM 86 SE Lockhart, 7 September 1984; allotype, ♀ imago, same data as for holotype; paratypes, 19 ♂ imagos, 22 ♀ imagos, 2 ♂ subimagos, 2 ♀ subimagos, same data as for holotype. Additional paratypes, 9 ♂ imagos, 9 ♀ imagos, 1 ♂ subimago, Texas: Bexar County, Salado Creek at Goliad Road in SE San Antonio, 27 August 1984; 16 nymphs, Texas: Bexar County, Salado Creek at Goliad Road in SE San Antonio, 29 July 1981; 12 nymphs, Texas: Bee County, Aransas River at Ryan Ranch E Papalote, 29 April 1982. All types were collected by J. R. Davis and are in alcohol. The holotype, allotype, 16 ♂ paratypes, 19 ♀ paratypes, and 12 nymphal paratypes are deposited in the collections of the United States National Museum of Natural History; the remaining types are deposited in the collections of Florida A&M University.

Additional material.—Two ♂ imagos, 2 ♀ imagos, 15 nymphs, Texas: Bexar County, Salado Creek at Southside Lion's Park in San Antonio, 26 July 1984; 2 nymphs, Texas: Hays County, Blanco River at old Austin Highway N San Marcos, 4 June 1985; 1 nymph, Texas: Travis County, Barton Creek at Camp Craft Road near Rollingwood, 23 May 1985; 2 nymphs, Texas: Travis County, Gilleland Creek 3.0 km SE Pflugerville, 27 August 1985. All specimens were collected by J. R. Davis and are in alcohol in the author's personal collection.

Remarks.—*Farrodes texanus* conforms to W. L. Peters' (1971) generic account, except for two characteristics of the male imago: (1) the fore tibiae are reduced by about 0.5 mm, with femora and tibial segments 1, 4, and 5 of relatively greater proportion, and tibial segments 2 and 3 of slightly lesser

proportion; and (2) only the apical one-third of the penes is divided, versus the apical two-thirds as previously described for the genus.

The new species, *Farrodes texanus,* is distinguishable from the three previously-described species of *Farrodes* by the following characters. (1) In the male imago, the size and shape of the ventral appendages arising from the penis lobes are unique, and the penes are only shallowly divided apically (Figs. 8, 9). (2) The abdominal color pattern, which is relatively uniform in males, females, and nymphs, is characteristic (Figs. 6 and 10). (3) In the male and female imagos, the spiracles, combined with the variation in wash on the tracheae, are very distinctive (Fig. 7). (4) In the nymphs, the brown banding on the tibiae and tarsi is unique (Fig. 10), and the caudal filaments bear distinct annulations at the articulations (Fig. 10). In contrast, the caudal filaments of previously-described species are uniformly pale.

Phylogeny

Farrodes texanus resembles the three previously-described West Indian species in a number of morphological respects, particularly in the nymphs. However, the new species obviously represents a separate evolutionary line with a considerable history of geographical isolation, judging from the degree of difference in male genitalia structure and the distinctive abdominal color pattern.

The Caribbean and Texas representatives are probably both derived from a South American ancestor. W. L. Peters (1971) stated that the relationships of the West Indian Leptophlebiidae clearly appear to be with those of Central and South America, and many biotic elements of southern Texas have Neotropical affinities and apparently are of Central or South American ancestry (Blair, 1950). In addition, recent phylogenetic studies indicate that *Farrodes* evolved in continental South America (W. L. Peters, 1986). On the basis of Halffter's (1974) model of dispersion, *Farrodes* probably invaded Texas during the early Pleistocene, with dispersal through the Mexican Transition Zone occurring along the eastern coastal plain.

Distribution

The first published account of the genus *Farrodes* consisted of descriptions of three species from the West Indian islands of Cuba, Jamaica, and Grenada by W. L. Peters (1971). At the time of Peters' report, no closely-related taxa were known even from circum-Caribbean continental areas. Subsequent collecting efforts have demonstrated, however, that *Farrodes* is widespread throughout tropical areas of continental South America, and the range is now known to extend from Argentina northward to southern Mexico, the West Indies, and southern Texas (W. L. Peters, 1986). Reports of leptophlebiids in Edmunds et al. (1976: 224) (as a segregate of *Homothraulus,* from Argentina, Guatemala, and Texas) and Allen and Brusca (1978: 424) (as *Thraulodes* sp. F, from Guatemala and Vera Cruz, Mexico) are now known to be referrable to *Farrodes* (R. K. Allen and H. M. Savage, personal communication). In addition, specimens of *Farrodes* from Venezuela and Peru have recently been reared by H. M. Savage and from Panama by R. W. Flowers, and W. L. Peters has recently collected the genus in Trinidad (H. M. Savage and W. L. Peters, personal communication). *Farrodes texanus* is apparently a disjunct, isolated unit of the genus, as years of collecting by R. K. Allen along the east coast of Mexico between Vera Cruz and Texas have failed to produce *Farrodes.*

The invasion of southern Texas by *Farrodes* has been promoted by the favorable climate together with the presence of small, rocky-bottomed streams. The genus has not colonized other climatically-suitable U.S. regions such as Florida, in spite of the proximity of Caribbean epicenters, probably due to physical habitat limitations imposed by

the predominance of unfavorable, lowland, sandy-bottomed streams (see Berner, 1950).

Farrodes texanus is thus far known only from seven scattered localities in southern Texas: two in the San Antonio River basin, two in the Guadalupe River basin, two in the Colorado River basin, and one in the Aransas River basin. Evidently, the genus also occurs in the Trinity River basin in northcentral Texas. As mentioned by Edmunds et al. (1976: 225), many years ago two adult male leptophlebiids were submitted to Edmunds for identification, with the following collection data: Texas: Dallas County, Elm Fork Trinity River below Carrollton Dam, 20 November 1949, Louis E. Moore (G. F. Edmunds, Jr., personal communication) (i.e. collecting locality #16 of Moore, 1950). The specimens were identified as a probable new genus and returned at the sender's request. The material subsequently has been lost (W. L. Peters, personal communication), so the actual identity will never be known. However, through recollection of the characters, Edmunds believes that the specimens were *Farrodes*.

All *F. texanus* collection localities, except that on the Aransas River, are proximal to the Balcones Escarpment, the northern boundary of neotropical influence (Blair, 1950). In this region, winter temperatures are ameliorated by warm, moist air moving inland from the Gulf of Mexico, and small, rocky-bottomed streams are numerous. To the north and west, winter temperatures probably are limiting, while to the east, unfavorable sandy-bottomed streams become increasingly predominant.

Farrodes texanus is seldom encountered, and is generally not abundant where it occurs. Its uncommon occurrence is evidenced by the failure of Henry (1981) to record it during an extensive survey of the mayflies of the Concho River basin, a single locality record during a similar survey of the Guadalupe River basin by M. S. Peters (1977) (not reported in Peters, but discussed by Edmunds et al., 1976: 225), and by the author's rare encounters with it during 11 years of collecting throughout Texas.

Habitat and Biology

Farrodes texanus nymphs have been found only in small, warmwater streams having an abundance of rocky-bottomed, riffle habitat, at an altitudinal range of 24 to 177 m above msl. These streams are alkaline, well-oxygenated, and relatively clear, with low concentrations of oxygen-demanding substances, ammonia nitrogen, and nitrate nitrogen (Table 1). Total phosphorus was elevated at three sites located in recovery zones below small sewage treatment plant discharges (Plum Creek, Gilleland Creek, Aransas River). The species was absent at a physically suitable site further upstream on the Aransas River, closer to the effluent source, which suggests a high sensitivity to organic pollution. Its occurrence has always been associated with diverse macrobenthic communities (Table 1), a further indication that its presence reflects clean water and healthy environmental conditions.

Nymphs typically occur in shallow water near the stream banks, along the edges of riffles where current velocities are reduced and some sediment deposition occurs. They are usually found on the underside of cobblestones that support small growths of periphytic algae. Specimens were occasionally found in swift current in the center of riffles at sites where other leptophlebiids were scarce or absent, which suggests a facultative ability to exploit true erosional microhabitats under conditions of low competition.

From four to eight other mayfly species occurred sympatrically, and from zero to three other leptophlebiids (*Thraulodes gonzalesi, Choroterpes* (*Neochoroterpes*) *mexicanus, Traverella presidiana*). *Farrodes texanus* was generally spatially segregated from other species. When other leptophlebiids were abundant, they predominated in swift-current areas, with *F. texanus* restrict-

Table 1. Biological and physicochemical parameters for water quality sampling stations at which *Farrodes texanus* n. sp. was collected. Numbers in parentheses indicate the number of determinations comprising the data base.

Locality	Biological Parameters		Physicochemical Parameters**		
	Community Diversity (*H*)*	*F. texanus* Relative Abundance	D.O.	Temp.	pH
Aransas R. @ Ryan Ranch E Papalote	4.04	222/m²	6.8–11.1 (4)	21.9–27.2 (4)	7.8–8.3 (4)
Salado Cr. @ Southside Lion's Park in San Antonio	4.15	108/m²	4.6–5.0 (4)	22.8–24.5 (4)	7.1–7.3 (4)
Salado Cr. @ Goliad Rd. In SE San Antonio	3.97	544/m²	7.1–7.2 (4)	22.5–24.1 (4)	7.4–7.6 (4)
Barton Cr. @ Camp Craft Rd. nr Rollingwood	3.11	5/m²	6.9–9.3 (4)	23.9–25.8 (4)	8.0–8.1 (4)
Plum Cr. @ FM 86 SE Lockhart	***	very common	4.8–5.6 (4)	26.3–26.9 (4)	7.4–7.7 (4)
Blanco R. @ old Austin Hwy. N San Marcos	***	occasional	6.8–8.6 (4)	27.8–30.0 (4)	8.0–8.2 (4)
Gilleland Cr. 3.0 km SE Pflugerville	***	occasional	5.1–6.9 (3)	24.1–25.9 (3)	7.7–8.0 (3)
Cumulative ranges			4.6–11.1 (27)	21.9–30.0 (27)	7.1–8.3 (27)

* Calculated according to the equation described by Shannon and Weaver (1963).

** Units for all parameters in milligrams per liter, except temperature (°C), pH (standard units), specific conductance (μmhos/cm), and flow (cubic feet per second).

*** No diversity index available due to lack of quantitative data. However, qualitative sampling revealed high community diversity in each case.

ed to riffle margins. Conversely, when other leptophlebiids were less numerous (as in Salado Creek at Goliad Road) or absent (as in the Aransas River), *F. texanus* exhibited its greatest abundance and was able to exploit erosional microhabitats. A degree of interspecific spatial niche overlap did occur at some sites, particularly with *T. gonzalesi* which occurred sympatrically at five sites. However, when the two species overlapped, they were seldom found together on the same rock, which seemingly reflects an avoidance mechanism. In addition to previously discussed physiographic and climatic factors, competitive exclusion by other leptophlebiids may also be a factor limiting the range of *F. texanus,* whose northern and western range limits correspond to the southern and eastern range limits of a number of leptophlebiid species.

Foregut contents of nymphs from Salado Creek and the Aransas River consisted almost entirely of detritus and fine sand, along with small numbers of diatoms. Thus, the

Table 1. Extended.

Physicochemical Parameters**							
Spec. Cond.	BOD_5	TSS	NH_3-N	NO_3-N	T-P	TDS	Flow
2010–2030 (4)	0.5 (1)	<10 (1)	<0.02 (1)	0.88 (1)	2.19 (1)	1120 (1)	13 (1)
635–673 (4)	1.0 (1)	33 (1)	0.10 (1)	0.87 (1)	0.17 (1)	366 (1)	22 (1)
595–647 (4)	1.0 (1)	24 (1)	0.02 (1)	0.89 (1)	0.15 (1)	352 (1)	25 (1)
455–461 (4)	1.0 (1)	7 (1)	0.05 (1)	0.04 (1)	0.04 (1)	260 (1)	9 (1)
1109–1124 (4)	0.5 (1)	30 (1)	<0.02 (1)	3.72 (1)	1.45 (1)	670 (1)	3 (1)
375–387 (4)	1.0 (1)	<5 (1)	<0.02 (1)	0.02 (1)	0.02 (1)	196 (1)	37 (1)
1271–1285 (3)	1.5 (1)	12 (1)	<0.02 (1)	0.15 (1)	4.10 (1)	704 (1)	1 (1)
375–2030 (27)	0.5–1.5 (7)	<5–33 (7)	<0.02–0.10 (7)	0.02–3.72 (7)	0.02–4.10 (7)	196–1120 (7)	1–37 (7)

species apparently is a detritivore that feeds by gathering decaying fine particulate organic matter.

In rearing chambers exposed to natural photoperiods, subimagos emerged at dusk and molted at sunrise. Although not observed, mating probably occurs in the morning in full sunlight. Such a cycle has been reported for *Farrodes hyalinus* in Jamaica (W. L. Peters, 1971). Mature nymphs were collected from April through September, indicating that emergence occurs for at least six months of the year.

Acknowledgments

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